Spatial Patterns of Soil Erosion and Deposition in Two Small, Semi-arid Watersheds

M.A. Nearing[1], Akitsu Kimoto[1], M.H. Nichols[1], Jerry C. Ritchie[2]

[1]USDA-ARS Southwest Watershed Research Center, Tucson, AZ 85719
[2]USDA-ARS Hydrology and Remote Sensing Laboratory, Beltsville, MD 20705

Abstract

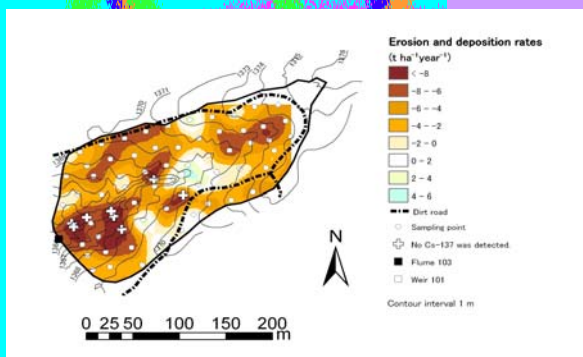
This work investigates spatial patterns of hillslope erosion in a semiarid ecosystem considering influences of vegetation, slope, rocks, and landscape morphology. ^{137}Cs inventories were measured on one shrub and one grassed watershed in southeastern Arizona. Mean erosion rates in eroding areas were 5.6 and 3.2 t ha^{-1} yr^{-1}, and net erosion rates for the entire watershed, including depositional areas, were 4.3 and nearly zero t ha^{-1} yr^{-1} for the shrub and grass watersheds, respectively. Differences in hillslope erosion rates between the two watersheds were apparently due to vegetation and erosion rates within the watersheds were not correlated to slope gradient or curvature, but were correlated to rocks in the upper soil profile. The study showed that measurement of sediment yield from a watershed can be a poor indicator of erosion taking place within the watershed. Sediment yield was controlled by watershed morphology, and in particular, the degree of channel incision.

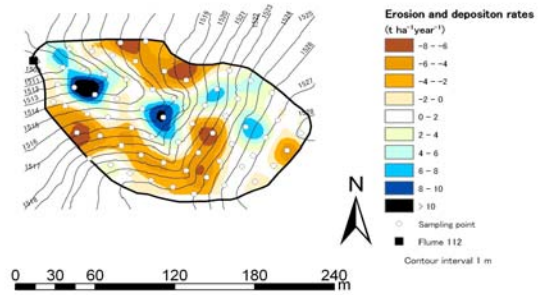
Lucky Hills watershed:
3.7 ha, 7.7% mean slope, shrub dominated, approximately 25% canopy cover, 290 mm annual rainfall.

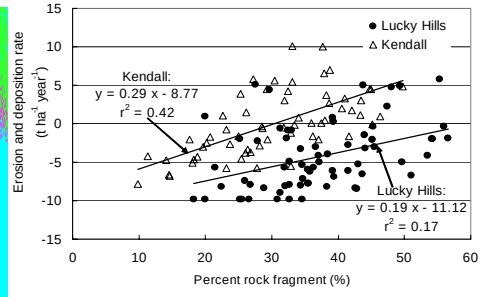
METHODS

1. ^{137}Cs inventories were collected at 68 sampling points in Lucky Hills and at 62 points in Kendall
2. Twenty reference soil surface samples were also taken at sites with assumed negligible erosion in the area.
3. Soil erosion and deposition rates were calculated comparing ^{137}Cs of the samples to the ^{137}Cs of the un-eroded reference sites.

Kendall watershed:
1.9 ha, 12.3% mean slope, largely vegetated with grass with a trace of shrubs and forbs, approximately 35% canopy cover, 315 mm annual rainfall.







RESULTS

1. 85% of all of the sampling points in Lucky Hills showed erosion, compared to 53% for Kendall, while 15% of all of the points in the Lucky Hills watershed showed deposition, compared to 47% for Kendall.
2. There was more net soil loss from the Lucky Hills watershed than from the Kendall watershed. The mean of the soil erosion and deposition in Lucky Hills was -4.3 t ha^{-1} yr^{-1}, while the mean in Kendall was +0.1 t ha^{-1} yr^{-1} (which was not significantly different from zero).
3. Erosion rates were greater in Lucky Hills than in Kendall. The mean for points of erosion in Lucky Hills was -5.6 t ha^{-1} yr^{-1} and for Kendall was -3.2 t ha^{-1} yr^{-1}.
4. Deposition rates were greater in Kendall. The mean for points of deposition in Lucky Hills was +3.4 t ha^{-1} yr^{-1} and for Kendall was +3.9 t ha^{-1} yr^{-1}.
5. There was a significant positive linear relationship between soil erosion and percent ***rock fragments*** in both Kendall and Lucky Hills.
6. Erosion rates on eroding portions of the hillslope were ***not*** correlated to slope gradient or curvature.

IMPLICATIONS

1. The evidence here suggests that the differences in hillslope erosion rates between the two watersheds were controlled largely by the vegetation differences, while within watersheds variation in hillslope erosion rates appeared to be dominated by rocks. The interpretation regarding vegetation is consistent with the interpretations related to the degree of patchiness of the vegetation. The grass cover in the Kendall watershed was certainly less patchy than that of Lucky Hills, wherein the shrubs were essentially lone plants separated by relatively wide inter-plant open spaces. Less erosion in the areas with higher percentages of rock fragments may be explained by the reduction of sediment transport capacity of flow with increasing hydraulic resistance on stony surfaces (i.e., slope-velocity equilibrium) [Nearing et al., 1999; Poesen et al., 1999]. Slope at sampling points and slope curvature did not appear to have a dominant influence on the hillslope erosion rates.
2. The delivery of eroded soil to the outlet of each watershed appears to have different controls than those controlling hillslope erosion rates. The difference in deposition between the two watersheds was due to differences in the watershed and drainage network morphology. The Lucky Hills watershed has a strongly incised channel network which facilitated transport of eroded sediments from the watershed. Conversely, the Kendall watershed had a swale area in which runoff slowed, allowing much of the sediment in the runoff from the hillslopes to deposit before it left the watershed outlet.
3. An important implication of the results of this study is that sediment yield from a watershed may have little to do with the rates of erosion within the watershed. The results from this study for the Kendall watershed are illustrative of the point. Even though the net erosion in the watershed was small, and even though past measurements show sediment yield rates to be quite small, there was net erosion taking place on 50% or more of the Kendall watershed area at rates as high as 7.9 t ha^{-1} yr^{-1}. Hillslopes at Kendall have been eroding over the past 40 years, even though very little sediment is being exported.